National Aeronautics and Space Administration

NASA's Earth Observing Missions & Measurements

Producing Information for Generations

Dr. Stephen Volz
Associate Director for Flight Programs
Earth Science Division, Science Mission Directorate

Outline of Presentation

- Integrated approach to Earth System Science
- Working from an established foundation
  - Missions in Orbit
  - Missions in Formulation & Development
- Augmentation & New Scope
  - Missions
  - Instruments
  - Airborne Science
- NASA Earth Science Data Systems Contributions
- Data Systems Challenge and Charter

The INTELLECTUAL CHALLENGE

- The Earth is an integral, complex system
  - Many processes, with varying time and spatial scales
  - Quantitatively describing the interactions between processes is key
- Measurements must span all important variables, and all important scales – time and space
- Research leads to greater understanding, which is codified in numerical models – prediction
- Societal benefits result when understanding is combined with measurements to generate useful information products

NASA's APPROACH

- Spaceborne measurements feature global coverage, high spatial resolution, and frequent revisit
  - Indirect measurements must be validated
  - Stability and accuracy are essential for trend detection
  - Multiple missions needed for proper sampling
- A comprehensive suite of missions and instruments is required to measure all important quantities
- Inter- and cross-disciplinary research and applications programs are needed to:
  - Synthesize complementary measurements from multiple missions
  - Advance the use of spaceborne measurements by non-mission scientists and other stakeholders

NASA Earth Science Efforts Concentrated in 6 Areas

- Planning, Building and operating Earth observing satellite missions, most with international and/or interagency partners — **Flight projects**
- Making high-quality data products available to the broad science community — **Data Systems**
- Conducting and sponsoring cutting-edge research in 6 thematic focus areas — **Research & Analysis**
  - Field campaigns to complement satellite measurements
  - Modeling
  - Analyses of non-NASA mission data
- Conducting an Applied Science program to improve the utilization of the data through the U.S. — **Applied Science**
- Developing technologies to improve Earth observation capabilities, providing the seed technologies for the next generation of earth observing instruments — **Earth Science Technology**
- Education and Public Outreach — **E/PO**

What information you need depends on what you are trying to accomplish.

- Measuring Climate Change:
  - Model validation - gridded contiguous data with uncertainties in each grid cell
  - Long-term time series – bias assessment is the must
- Studying phenomena using multi-sensor data:
  - Consistently processed and presented fusion data sets with quality information
- Realizing Societal Benefits through Applications:
  - Near-Real Time for transport and event monitoring - in some cases, coverage might be more important that quality
  - Monitoring (e.g., air quality exceedance levels) – uncertainty
- Educational (users generally not well-versed in the intricacies of quality; just taking all the data as usable can impair educational lessons) – only the best products

Earth Science Data systems have multiple constituencies

National Aeronautics and Space Administration

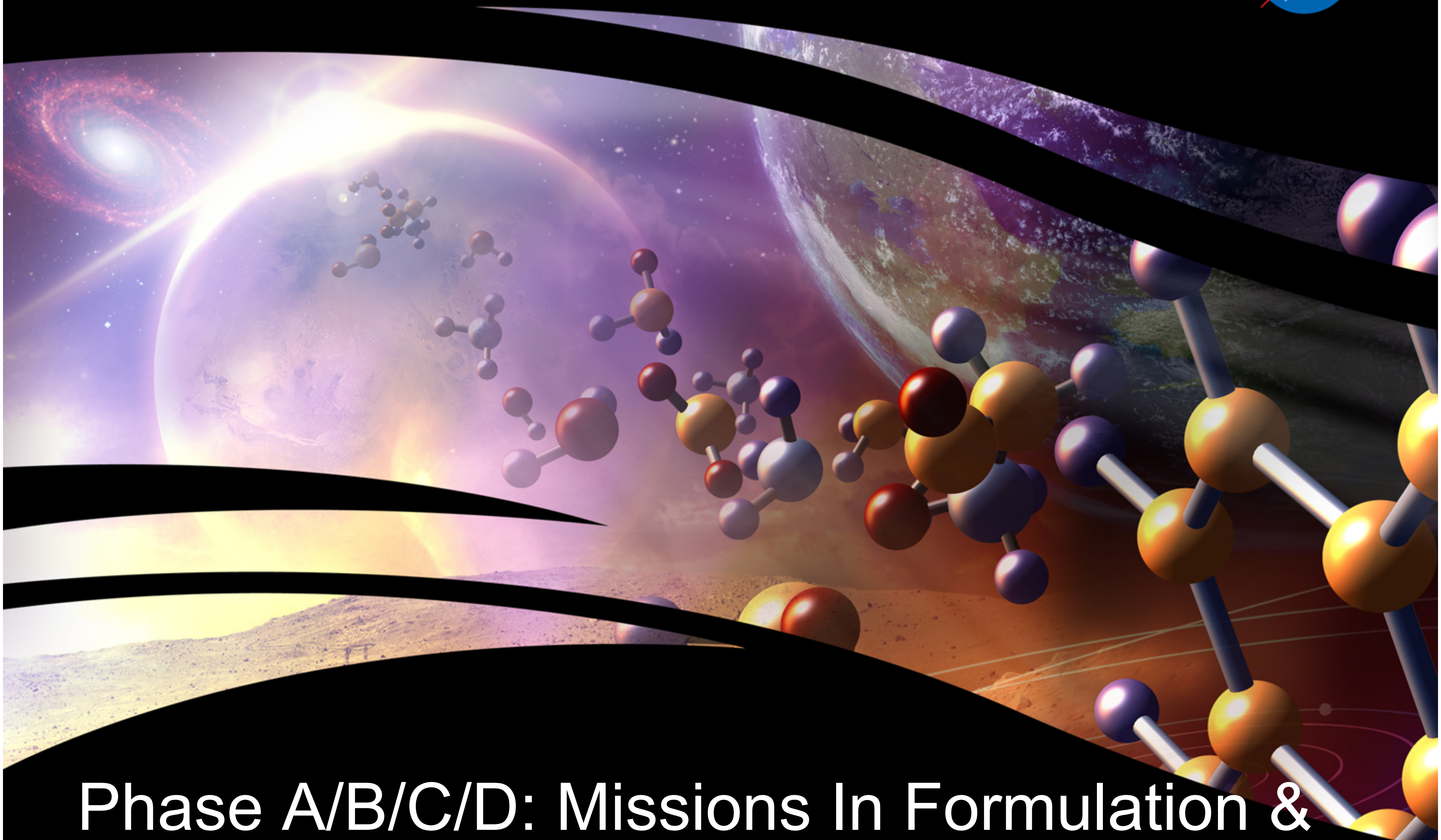
Phase E: Missions In Operation


NASA Operating Missions
OSTM/Jason 2
Jason
QuikSCAT
ACRIMSAT
Landsat-7
EO-1
SORCE
TRMM
Aqua
Terra
GRACE
ICESat
CALIPSO
CloudSat
Aura

Constellation Flying: The Morning & Afternoon Constellations

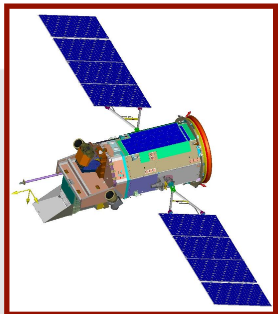
- Constellations are organic, evolving over time as old missions drop out and new ones come in.
- Our objective is to have continuous and ever improving information and knowledge of the Earth System

National Aeronautics and Space Administration

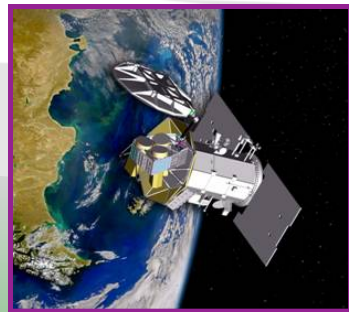


Phase A/B/C/D: Missions In Formulation & Development

ESD Missions in Development & Formulation

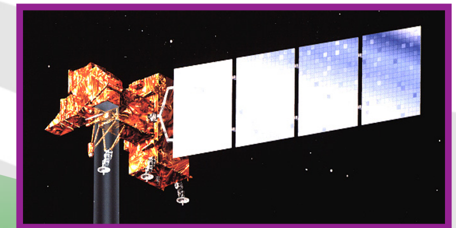


GLORY
2010 (TBR)
Phase D



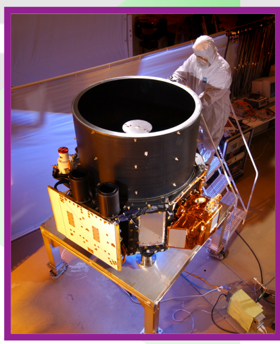
AQUARIUS
Apr 2011
Phase D

NPP
Oct 2011
Phase D



LDCM
Dec 2012
Phase C

Phase A

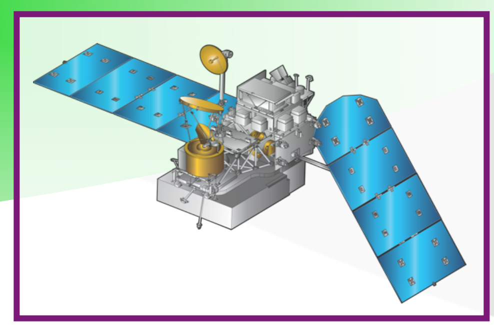


ICESat-2
Oct 2015

Phase B

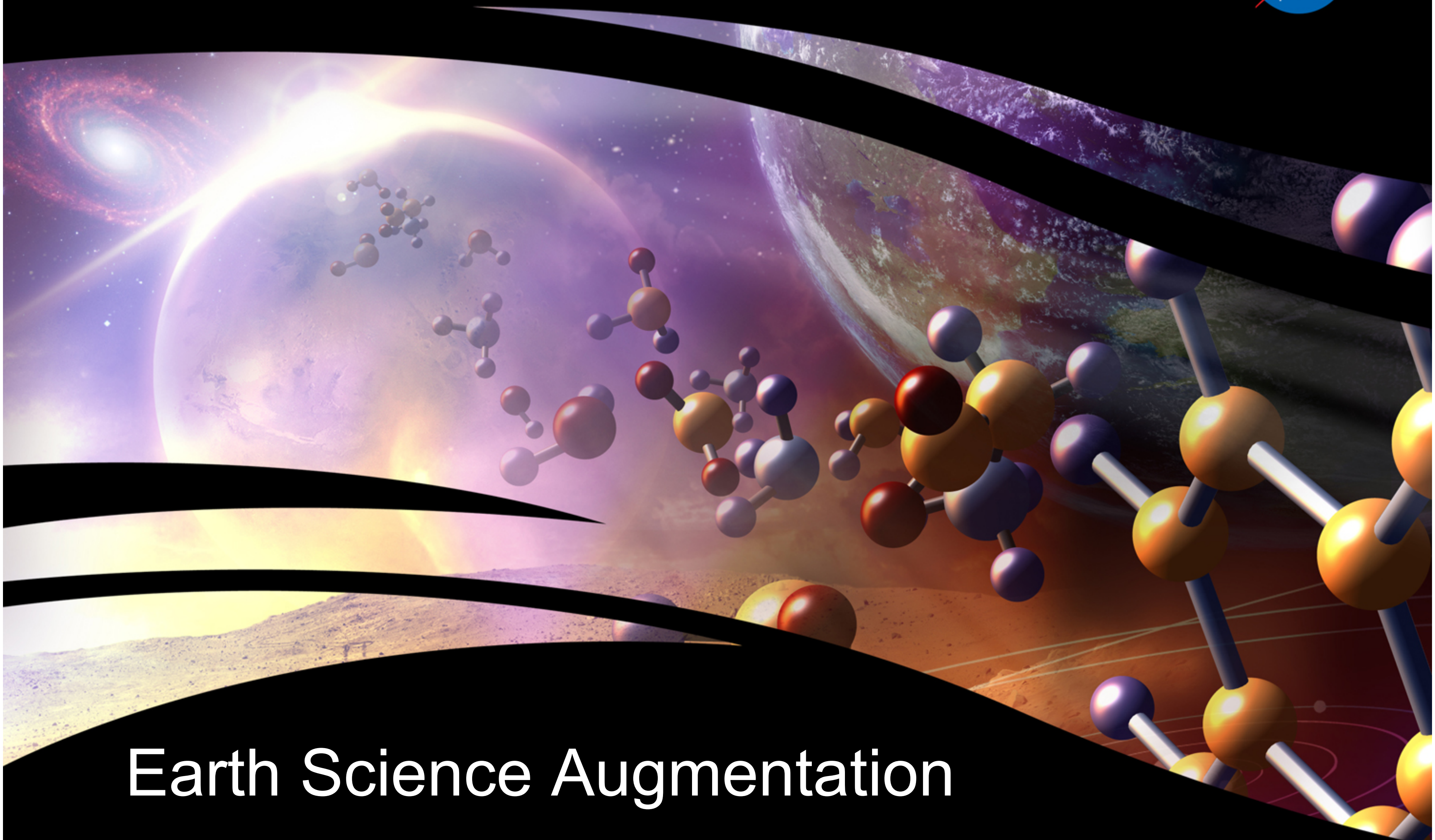
SMAP
Nov 2014

Phase C



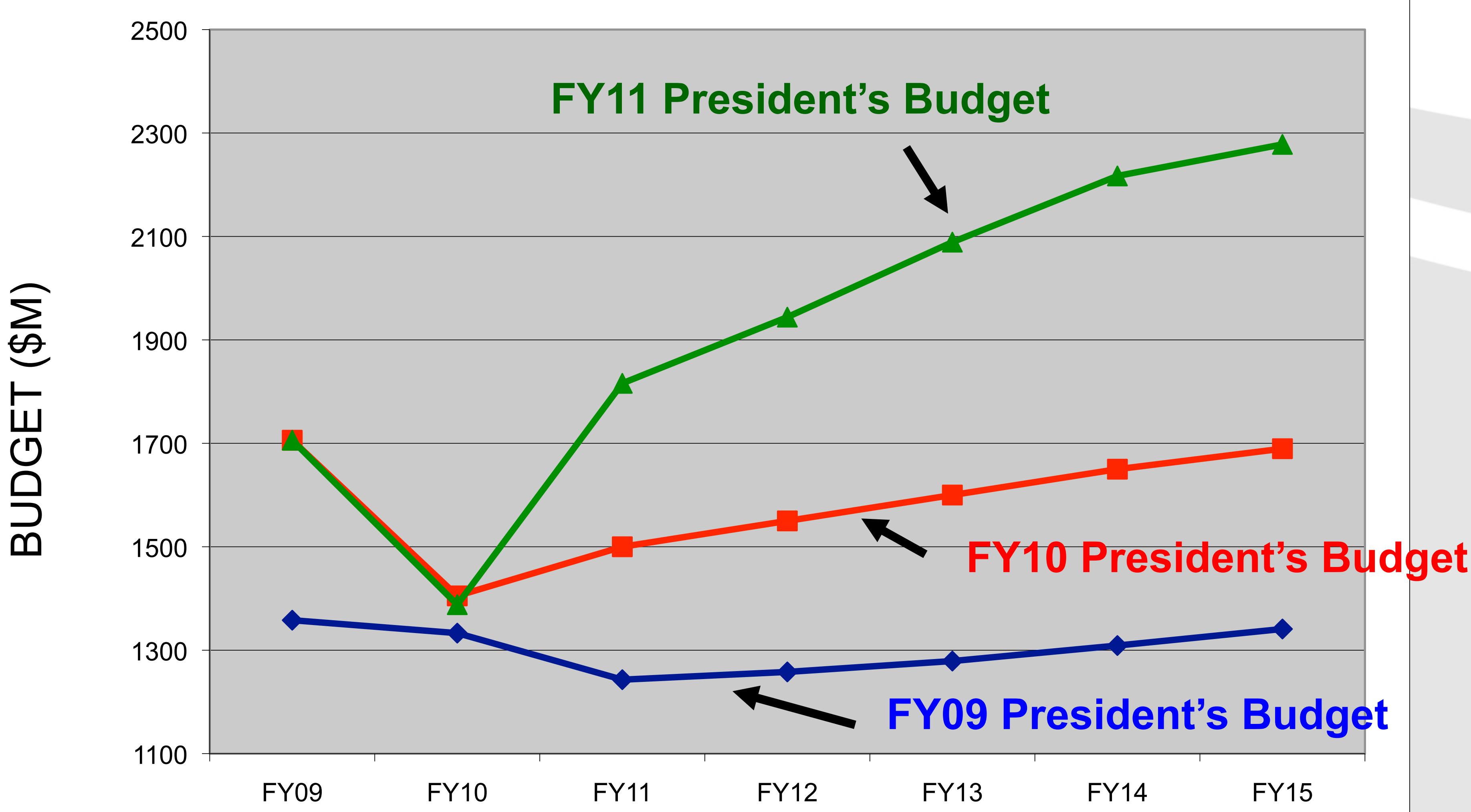
GPM
Jul 2013
Nov 2014

National Aeronautics and Space Administration



Earth Science Augmentation

President's FY2011 Budget for Earth Science



Missions Distributed by NASA Flight Project Life Cycle

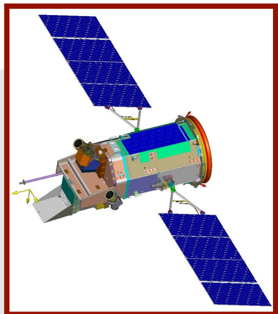
Project Life Cycle							
Project Pre-Formulation	Project Formulation		Approval (For Implementation)	Project Implementation			
Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F	

Pre-Phase A	Phase A	Phase B	Phase C/D	Phase E/F
NASA: DESDynI CLARREO SWOT ASCENDS ACE GEO-CAPE HyspIRI GRACE FO PACE	NASA: ICESat-2 SAGE III	NASA: SMAP OCO-2 Venture EV-1	NASA: NPP Glory Aquarius GPM LDCM	NASA Prime: Aura OSTM Extended: Aqua Terra TRMM Jason EO-1 QuikSCAT SORCE Acrimsat CALIPSO CloudSat GRACE
10	4	6	6	13
NASA/NOAA: QuikSCAT FO	NASA/NOAA: Jason-3 JPSS-2	NASA/NOAA: TSIS CERES FM6 JPSS-1	NASA/NOAA: GOES-R/S	

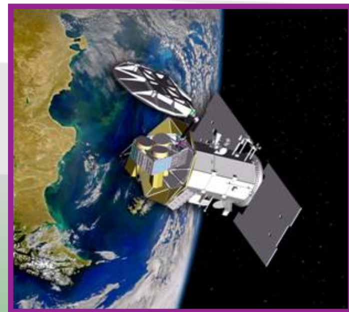
National Aeronautics and Space Administration

Phase A/B/C/D: Missions In Formulation & Development with Augmentation

ESD Missions in Development & Formulation

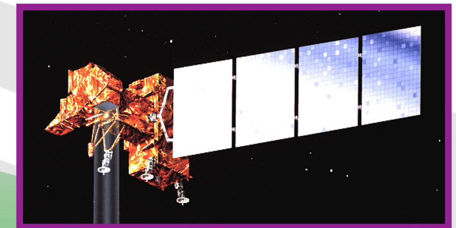


GLORY
2010 (TBR)
Phase D



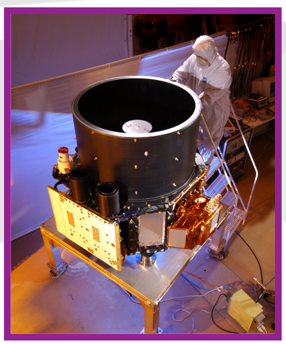
AQUARIUS
Apr 2011
Phase D

NPP
Oct 2011
Phase D



LDCM
Dec 2012
Phase C

Phase A

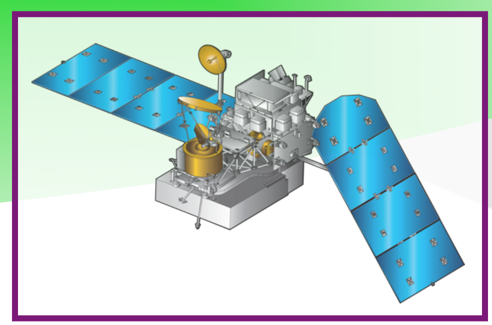


ICESat-2
Oct 2015

Phase B

SMAP
Nov 2014

Phase C

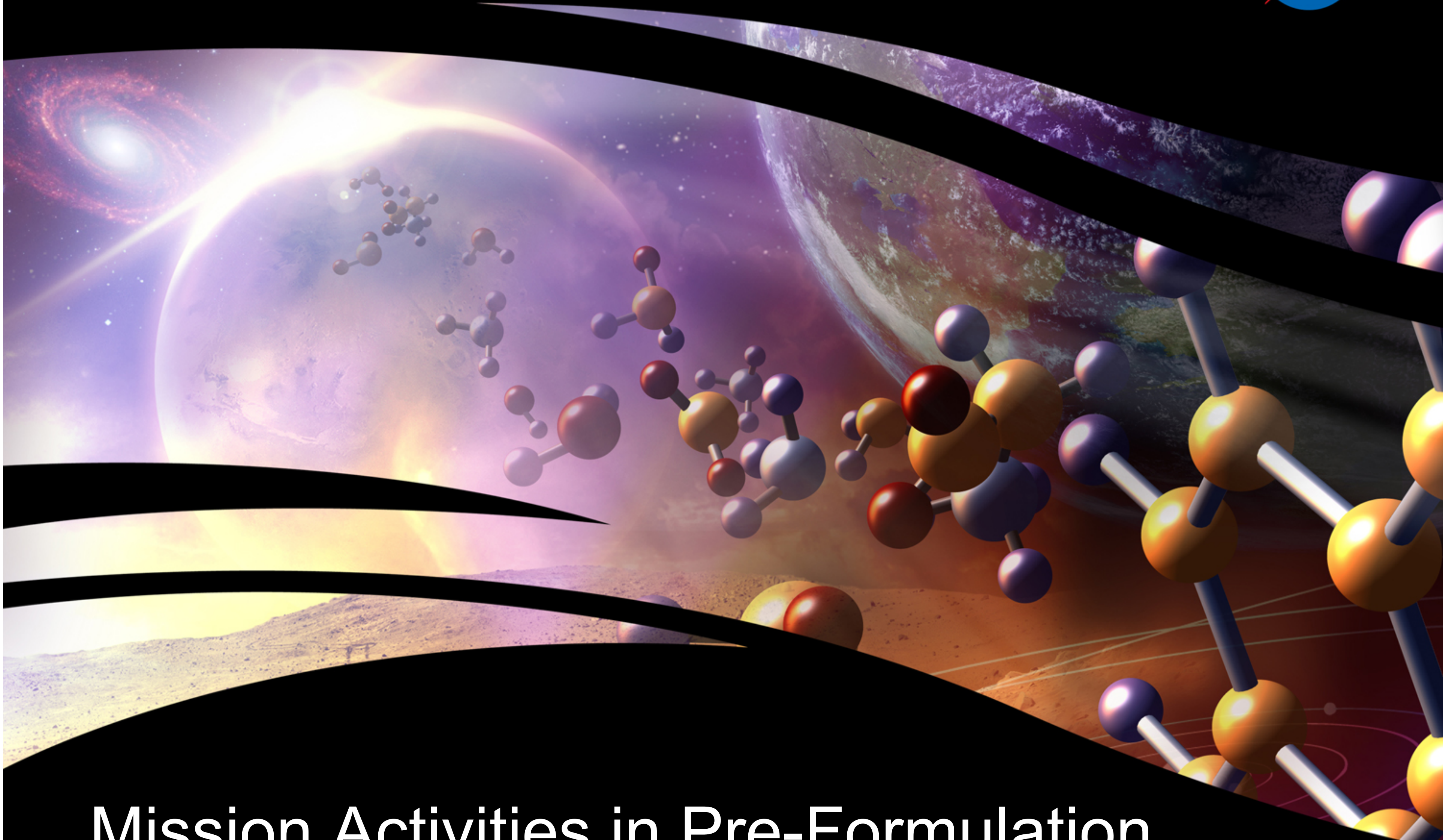


GPM
Jul 2013
Nov 2014

Phase B

OCO-2
Feb 2013

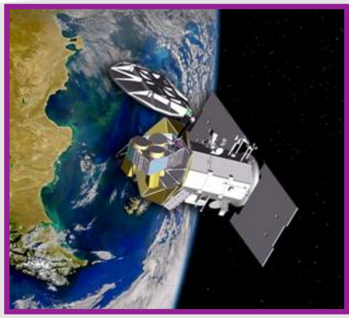
National Aeronautics and Space Administration



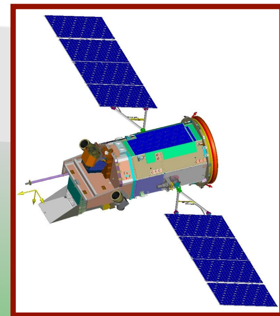
Mission Activities in Pre-Formulation

ESD Missions in Pre-Formulation thru 2020

Phase A



SAGE III 2014



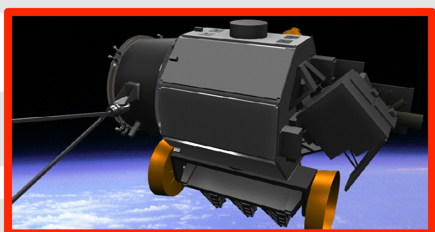
GRACE FO
2016

DESDynI
Lidar & Radar
2017

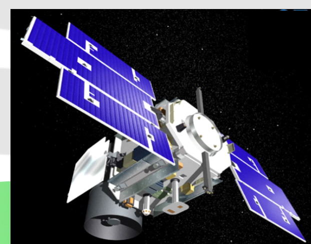
CLARREO-1
2017

EV-2
2018

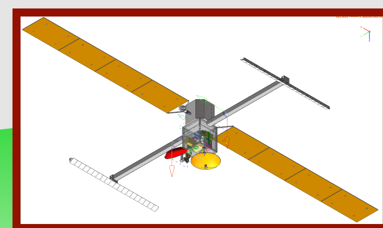
Pre Phase A



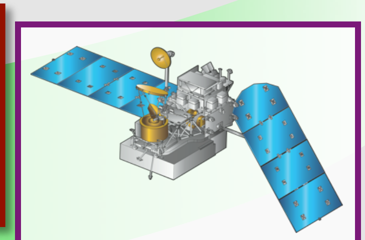
CLARREO-2
2020



ASCENDS
2020

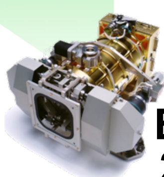


SWOT
2019

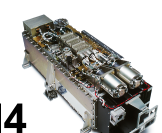


PACE
2019

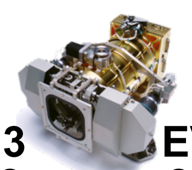
Instrument Developments



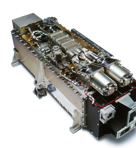
EV-I4
2019



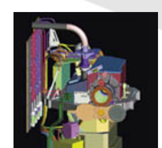
EV-I3
2018



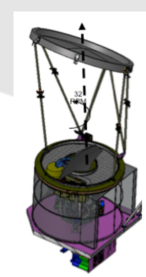
EV-I2
2017



EV-I1
2016



OCO-3
2015



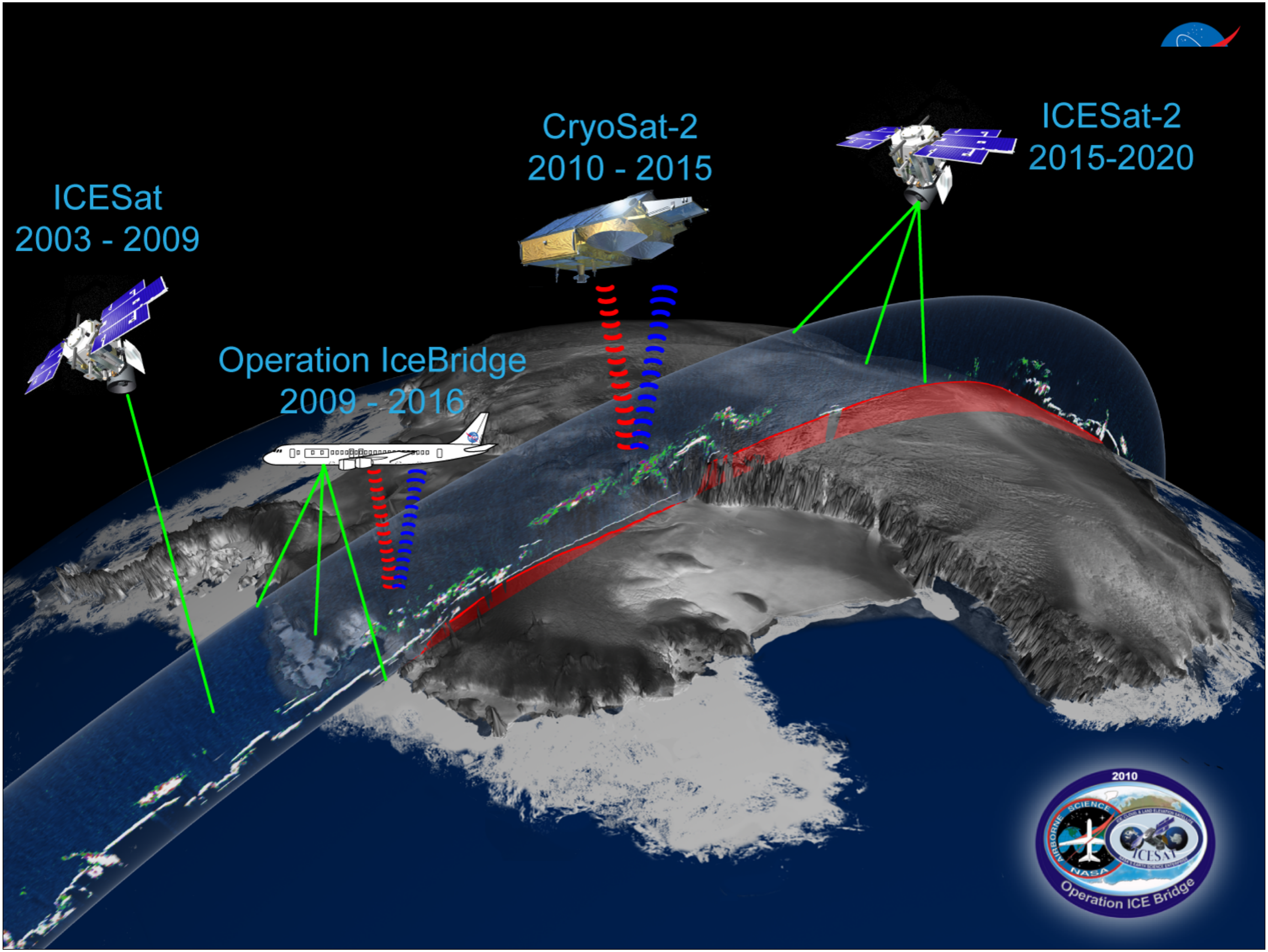
GMI#2
2013

Earth Science Observations are more than Satellites

- Instrument Missions of Opportunity (MoOs)
- Airborne, for observations, instruments, and simulators
  - Including Operation IceBridge & multiple Earth Venture 1 airborne campaigns
- Advanced instrument and technology investments for future satellite hardware
- Ground calibration of instruments for better absolute accuracy
- Airborne and ground sites for flight validation

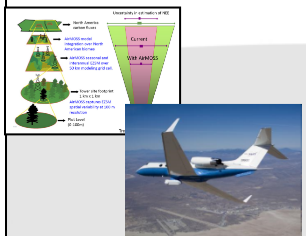
Data integration is needed across all of these platforms and activities in addition to data from the orbiting satellites

Operation IceBridge: using instrumented aircraft to bridge the observational gap between ICESat and ICESat-2



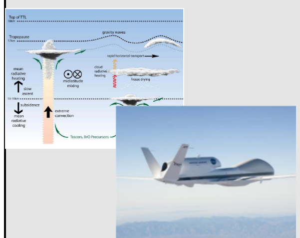
ICESat
2003 - 2009
CryoSat-2
2010 - 2015
ICESat-2
2015-2020
Operation IceBridge
2009 - 2016
2010
AIRBORNE SCIENCE
NASA
ICESAT
Operation ICE Bridge

Earth Venture-1 Investigations: 2011 - 2014



Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) - Univ Mich/JPL

North American ecosystems are critical components of the global exchange of the greenhouse gas carbon dioxide and other gases within the atmosphere. To better understand the size of this exchange on a continental scale, this investigation addresses the uncertainties in existing estimates by measuring soil moisture in the root zone of representative regions of major North American ecosystems. Investigators will use NASA's Gulfstream-III aircraft to fly synthetic aperture radar that can penetrate vegetation and soil to depths of several feet.



Airborne Tropical Tropopause Experiment (ATTREX) - ARC

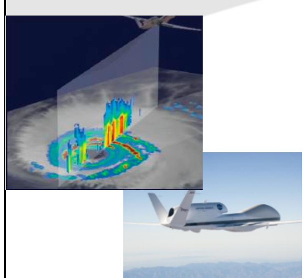
Water vapor in the stratosphere has a large impact on Earth's climate, the ozone layer and how much solar energy the Earth retains. To improve our understanding of the processes that control the flow of atmospheric gases into this region, investigators will launch four airborne campaigns with NASA's Global Hawk remotely piloted aerial systems. The flights will study chemical and physical processes at different times of year from bases in California, Guam, Hawaii and Australia.

Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) - JPL

This investigation will collect an integrated set of data that will provide unprecedented experimental insights into Arctic carbon cycling, especially the release of the important greenhouse gases such as carbon dioxide and methane. Instruments will be flown on a Twin Otter aircraft to produce the first simultaneous measurements of surface characteristics that control carbon emissions and key atmospheric gases.

Deriving Information on Surface Conditions from COlumn and VERtically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) - LaRC

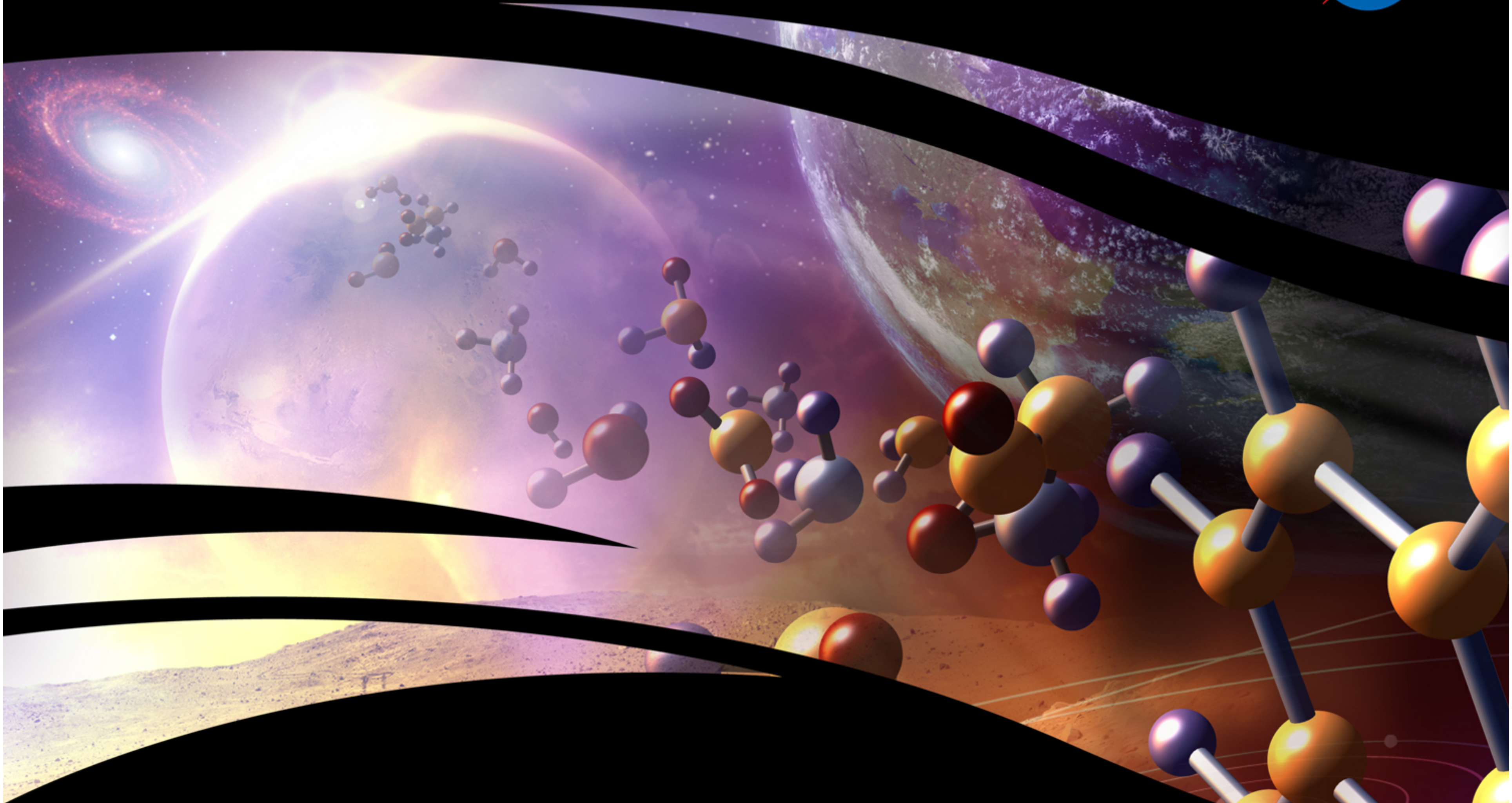
The overarching objective of the DISCOVER-AQ investigation is to improve the interpretation of satellite observations to diagnose near-surface conditions relating to air quality. NASA's B-200 and P-3B research aircraft will fly together to sample a column of the atmosphere over instrumented ground stations.



Hurricane and Severe Storm Sentinel (HS3) – GSFC/ARC

The prediction of the intensity of hurricanes is not as reliable as predictions of the location of hurricane landfall, in large part because of our poor understanding of the processes involved in intensity change. This investigation focuses on studying hurricanes in the Atlantic Ocean basin using two NASA Global Hawks flying high above the storms for up to 30 hours. The Hawks will deploy from NASA's Wallops Flight Facility in Virginia during the 2012-14 Atlantic hurricane seasons.

National Aeronautics and Space Administration



Earth Science Data Systems Contributions

NASA's Continuing Commitment to a Broad Orbital Program

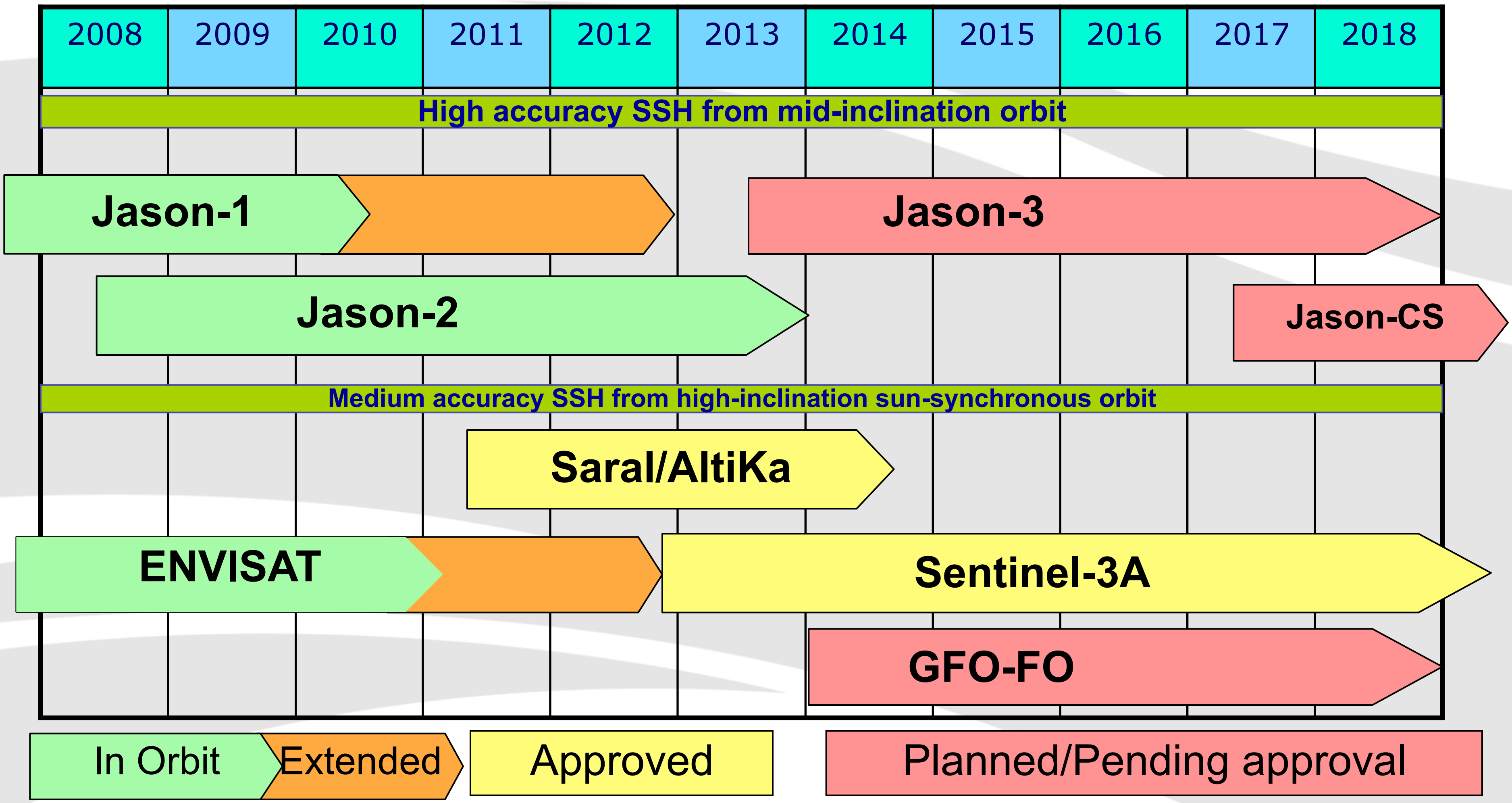
- NASA's current fleet on orbit is aging, but is generally healthy and continues to provide calibrated validated data sets being used with increasing return by users world wide
- Our missions currently in development will continue many but not all of the critical measurements, extending the EOS legacy
  - NOAA will be picking up some of the measurements (TSIS, CERES, VIIRS, OMPS, …)
- The recent augmentation has enabled NASA to reinvigorate the overall Earth Science program, enabling advancement on all fronts
  - Large missions – DESDynI, ASCENDS
  - Competitively selected small missions and instruments - Venture
  - Airborne science campaigns – IceBridge, EV-1
  - Augmented technology – ESTO, GPS TrIG
  - Comprehensive integrated science – R&A, modeling
  - Infrastructure – Geodetic Networks, High speed computing

Science Questions & Societal Benefits Returns Drive Expectations

- The addition of all the new activities have increased the expected throughput of measurements for 2015 and beyond
- The expectation is for quicker data usability, easier portability and more transparency
- State of Earth *System* science is demanding more fusion data products faster
- Operational users need a better understanding of what the higher level products will be, when they will have them, and how long they will continue
  - This places an emphasis on *product* continuity as opposed to *mission* continuity

- NASA's traditional mission development structure places responsibility on the mission teams to define the data management and utilization approach
  - Focus is on science and on Level 1 requirements
  - Broader and more long term objectives are not included in this scope

Example of Record-level Continuity: Ensuring continuity across generations of satellites



- The operational users shouldn't car where the data come from, as long as they can use it in a consistent way

2009 Charter to the Data Systems Working Group

From June 2009

- Define an approach to evolve what is working now into what we want to have in 2020 and beyond
- Keep what works within the existing systems, and identify what must be changed
- Consider how best to identify and involve the end user communities in the data system and product definition
- Define a recommended approach for guiding the new missions' data system definition and development
- Identify necessary actions and activities for the near term (0-2 years) that supports these developments

2010 Updated Charter to the ESDSWG

- Improve the consistency of mission data sets with clearer and more usable data standards
- Determine what enabling technologies we should be investing in to enhance the current ground systems to be ready by 2020 to handle the flood
- Help define methods to evolve the existing structure so the new systems being defined, by mission teams, can reuse existing approaches while meeting new demands
- Help define ways to improve data product continuity across platforms and generations of satellites to show operational users how we can provide seamless, quality information
- Improve mechanisms for exchanging key information with new mission teams to influence & guide their developments in the right path

Existing & Future Earth Science Fleet